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Dated: February 7, 2008 Lisa Adams

Docket No.: 102863-23
(ETH5081)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
R. C. Carney et al.

Application No.: 10/718,122 Confirmation No.: 9095

Filed: November 20, 2003 Art Unit: 1725

For: METHOD AND APPARATUS FOR LASER DRILLING WORKPIECES Examiner: M. A. Elve

SUBMISSION OF CERTIFIED TRANSLATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant hereby re-submits the submission filed on February 6, 2008. Applicant inadvertently omitted a copy of the certified translation of JP-HI-215290. It is respectfully requested that the attached certified translation be entered in the record and expressly considered during the prosecution of this application.

Applicant believes that no filing fee is due for the submission of this foreign patent translation, however, the Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 141449, under Order No. 102863-23.

Dated: February 7, 2008

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TRANSLATOR CERTIFICATION

I, Takayuki Ogawa, a translator fluent in the Japanese language, on behalf of Morningside Evaluations and Consulting, do solemnly and sincerely declare that the following is, to the best of my knowledge and belief, a true and correct translation of the document(s) listed below in a form that best reflects the intention and meaning of the original text.

MORNINGSIDE EVALUATIONS AND CONSULTING

Signature of Translator

Date: February 4, 2008

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SPECIFICATION

1. Title of the Invention

Laser processing method

2. Claims

1. A laser processing method in which a laser beam is focused with a lens and samples are processed by irradiating samples such as living cells, wherein the method comprises:

a back-and-forth motion of focusing the laser which is focused via said lens with a means of moving said lens in the direction of the optic axis; and

the processing of samples into a linear shape with a specified thickness via a means of moving a stage on which said samples are held, or a means of slanting the optic axis of the laser that passes through an objective lens.

3. Detailed Description of the Invention

Industrial Field of the Invention

The present invention relates to the processing of live samples with a means of irradiating a laser beam at the live samples of living cells such as ova or microorganisms.

Prior Art

Details of a laser perforation device for living cells as prior art are described in Japanese Examined Patent Application Publication S62-7837, and the area around the objective lens of the mechanism is shown in Figure 2.

The laser is most concentrated on the focal plane of A, forming a curve above or below the plane. A sample 3 of living cells or the like is perforated by situating the processing site on the focal plane, and in particular, very thin samples are cut by moving the stage on which the sample is held while irradiating with a laser.

Problems to be Solved by the Invention

The aforementioned prior art has a perforation function in which DNA or the like is transfused into a living cell as a main constituent, so sufficient consideration is not given to a cutting function. Consequently, a sample can be cut when it is thin enough in comparison to the focal depth of the beam as shown in Figure 2, which is capable of processing, but a sample having a spherical form with a diameter of approximately 100 μm such as a fertilized ovum cannot be cut.

For these reasons, it is necessary to manually move a sample in an up-and-down direction (Z direction) so as to move the sample in the Z direction, and at the same time, it is necessary to move the sample in the direction of cutting (X direction) as shown in Figure 3 when such thick samples are to be cut.

The objective lens of this system has the two functions of focusing the laser and acting as a microscope such as for obtaining magnified images of samples, and the function of a microscope is disrupted if the stage is moved in the Z direction as described in above. This means that the cutting operation will be performed without an awareness of the condition of the samples. Therefore, many samples die, because they often incur unnecessary damage when the laser is targeted at a living sample such as a fertilized ovum, thus leading to failure. In addition, the operation of manually moving the stage often requires considerable effort.

The purpose of the present invention is to provide a laser processing method that facilitates an easy cutting operation and particularly a cutting operation with an awareness of the cutting condition using a magnified image viewed via a microscope.

Means for Solving the Problems

The aforementioned purpose can be achieved by:

a back-and-forth motion of a focused laser that is focused by said lens with a means of moving said lens constituting a beam expander in the direction of the optic axis; and

with a means of moving a stage holding the samples or a means of slanting the optic axis of the laser beam that passes through the objective lens at the same time.

Action

When the lens constituting a beam expander is moved in the direction of the optic axis, the focal plane of the laser focused by the objective lens moves in the direction of the optic axis in a back-and-forth motion. With this condition, when the stage holding the sample is moved within the plane of the stage, the sample is processed in a linear shape with an approximate thickness by the moving distance of the optical axis of said focal plane.

In addition, instead of moving the stage in a plane, when the optical axis of the laser passing through the objective lens is deflected, the same processing of the aforementioned linear shape can be done by moving the focal plane within the plane of the stage. In both cases, the distance between the samples and the objective lens remains constant, so the conditions of processing the samples can be observed while effort for processing can be significantly reduced compared to the prior art.

Embodiment

Hereinafter, an embodiment of the present invention is described using Figure 1 and Figures 4 to 7. Figure 1 shows the overall configuration, and a laser 10 is guided by a light path deflection device 9 as part of a microscope 8 after the beam is adjusted by an optical interface 11 and passes through an objective lens 1. The laser that passes through the objective lens is narrowed at a low level and is irradiated at a sample 3 fixed on a stage 6 so that it processes the sample. A TV camera 16 for observing the image of the sample and an outline detector 17 that detects by comparing the circle portion of a sample and the irradiation point of the beam are provided. A stage controller 7 is provided for controlling the stage in a plane (XY directions) and in an up-and-down direction (Z direction) of the stage.

An optical interface 11 incorporates a beam expander 12 that controls the focal position of the laser narrowed by the objective lens, a lens-moving device 14 that moves the lens 13 constituting the beam expander along the optical axis, and a lens-moving controller 15 that controls the movement of said lens.

Secondly, a detailed description of said beam expander 12 is described with reference to Figure 4.

The two lenses on the left are lenses constituting a beam expander and the lens on the right is the objective lens in Figure 4. The focus of the beam narrowed by the objective lens is moved in the direction of the optic axis as shown in the figure by moving the lens of the beam expander in the direction of the optic axis, and the movement distance of the lens l and movement distance of the focus Δl are as shown in Figure 5 for example.

Therefore, when said operation is utilized, the distance between the samples and the objective lens is constant; that is, samples can be cut while being observed with a magnified image thereof.

Hereinafter, the action of the present invention is described with reference to Figure 1 and Figures 5 to 7.

When beginning to cut the samples, the lens of the beam expander begins to move back-and-forth along the distance (e.g., l_i in Figure 5) of the optical axis only as prescribed by the lens-moving controller 15 and the lens-moving device 14, and the focus narrowed by the objective lens is moved in the direction of the optic axis at the same pitch of movement of said lens by Δl_i in Figure 5.

With this condition, when a stage 6 is moved in the X direction, the sample is cut as shown in Figure 6. If the thickness of a sample is thinner than Δl in Figure 5, cutting will be done when it comes to the sample end (pint A in Figure 6).

In contrast, if the thickness of a sample is thicker than Δl, an outline detector 17 detects

it when it comes to the end of the sample, its signal is input to the stage controller 7, and the stage is elevated by the distance prescribed as shown in Figure 7. Afterward, the stage is moved in the inverse direction of the X direction and cutting is continued. The sample is cut by such repeated actions. In this case, the focal position of an image magnified by a microscope is moved over when the stage is elevated, but a new cross-section can be observed at that position, and the same surface can be observed until the stage is elevated the next time.

The ease of cutting the samples depends on the properties of the samples, and it can be handled by controlling the speed of movement of the lens and speed of movement of the stage if a sample is difficult to cut.

Meanwhile, a cross-section of a sample when a pulsed laser is utilized as the laser 10 is shown in Figure 7, and the radiating point is shown as circular points. This shows that the distance in direction Z of the radiating point is dependent on the speed of movement of the lens of the beam expander 12 and the pulse repetition frequency of the laser.

In addition, the distance in the X direction of the radiating point depends on the speed of movement in the X direction of the stage.

Thus, a sample can be cut in a perfect condition by controlling the lens-moving controller 15, the stage controller 7, and the pulse repetition frequency of the laser 10 according to values of properties of a sample as shown by 18 in Figure 1.

The method of moving the stage when cutting samples is described above, and when the thickness of a sample is thinner than $\Delta 1$ in Figure 5, the sample can be handled by locking the stage and changing the focal position (on the XY plane) of the objective lens by using the light path deflection device 9. In addition, concomitant use of the light path deflection device and the stage can be considered when a sample is thicker than $\Delta 1$.

Effect of the Invention

According to the present invention, the condition of processing can be observed with a microscope, as the distance between the surface of the sample being processed and the objective lens can be kept constant, even for a thick sample, so the effort in processing can be significantly reduced.

4. Brief Description of the Drawings

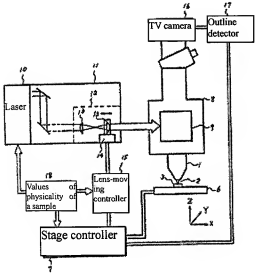
Figure 1 is an overall configuration of one embodiment of the present invention, Figure 2 and Figure 3 are elevation views of the objective lens proximity of the prior art, Figure 4 and Figure 5 are explanatory drawings of the operation of the beam expander, Figure 6 is an overhead view of one embodiment of the present invention, Figure 7 is a cross-sectional drawing of a sample when cutting and is the cross-section drawing in Figure 6, I–I.

1: objective lens; 6: stage; 7: stage

roller; 9: light path deflection device; 12: beam expander; 14: lens-moving device; 15: lens-moving controller; 16: TV camera; 17: outline detector.

Representative: Patent agent, Masao Ogawa

Fig. 1



1 objective lens
3 samples
6 stage
8 microscope
9 light path deflection device
12 beam expander
14 lens-moving device

Fig. 2

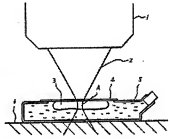
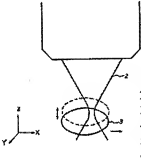
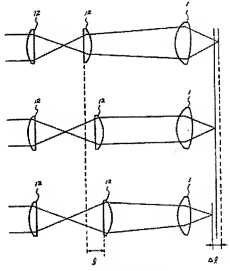


Fig. 3



1 objective lens
2 laser beam
3 samples
4 cover glass
5 culture-pot
6 stage

Fig. 4



1 objective lens
12 beam expander

Fig. 6

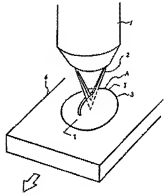
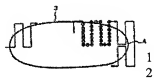


Fig. 7



1 objective lens
2 laser beam
3 samples
6 stage

Microscope with moving laser focus: Δ1 (μm)

Distance of movement of beam expander: l (mm)

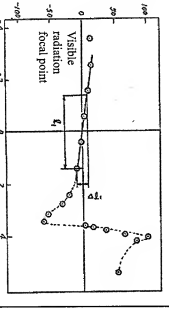


Fig. 5